Water budget concept

a balance sheet of gains, storage and losses:

IN	STORAGE	OUT
Drinking	Body Fluids	Urine
Preformed	Bladder	Faeces
Metabolic		Evaporation – body surface
Absorption - water		Evaporation - respiratory
- soil		Salt glands
- water vapour		

1

Overall water turnover rate

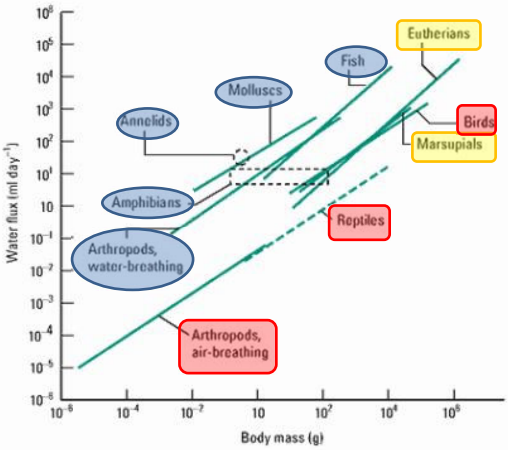


Fig. 15.9 Water flux rates in relation to body size for land animals; all show similar gradients, though arthropods have routinely lower fluxes than vertebrates, and soft-bodied animals much higher fluxes. (Adapted from Nagy & Peterson 1987.)

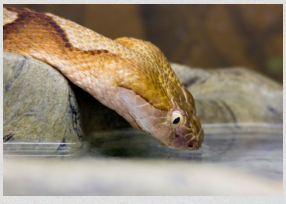
2

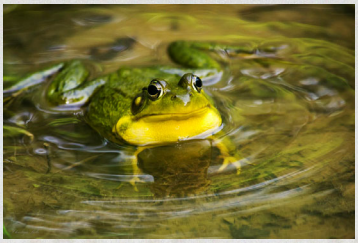
Intake - drinking

Liquid water

3

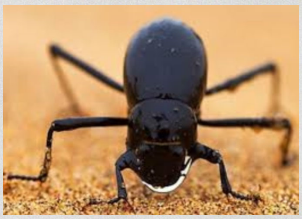
Vertebrates also drink (amphibians don't!)





4

Intake - drinking



Fog condensate

Namib desert beetles

Namib desert lizards, snakes, mammals, birds

Thorny devils

5

Soil drinking – spiders, frogs, beetles

From moist soil

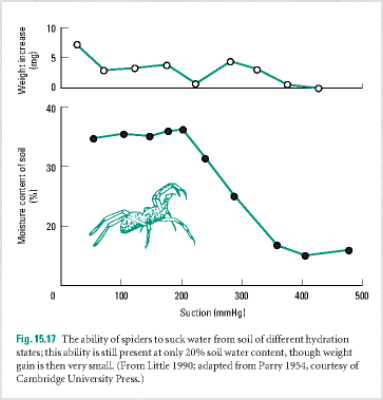


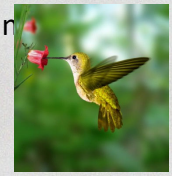
Fig. 15.17 The ability of spiders to suck water from soil of different hydration states; this ability is still present at only 20% soil water content, though weight gain is then very small. (From Little 1990; adapted from Parry 1954, courtesy of Cambridge University Press.)

6

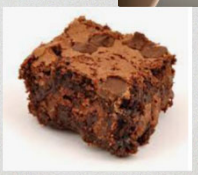
Preformed water

Pre-existing in

Lots



Some



Little

7

Metabolic water

$$\text{nutrients} + O_2 \rightarrow CO_2 + H_2O + \text{chemical energy} + \text{heat}$$

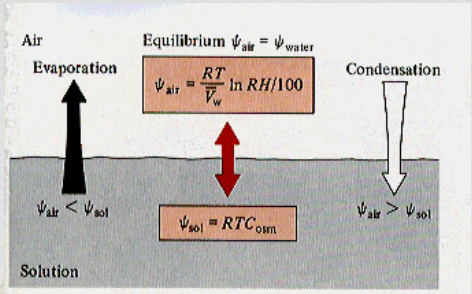
Nutrient	Metabolic water produced by oxidation	
	mL/100g	*mL/100 kcal*
Lipids	107	11.8
Carbohydrates	55	15
Proteins	41	10

8

Water vapour absorption

Many arthropods are able to perform the amazing trick of absorbing water vapour from sub-saturated air. This is quite a thermodynamic trick! It is a balance of:

- water loss by evaporation into sub-saturated air (depends on ambient RH)
- Water gain by condensation into solution (depends on osmotic concentration)

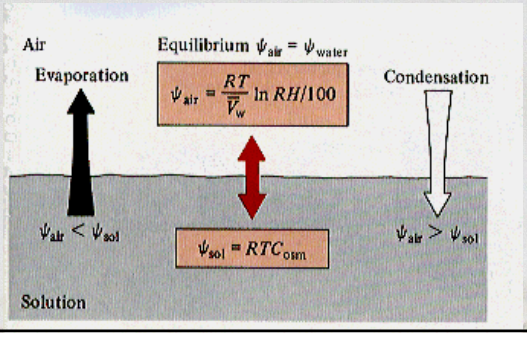


9

Water vapour absorption

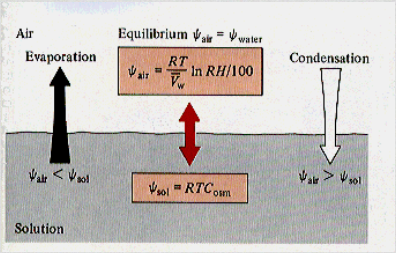
The water vapour potential difference between a solution and air usually greatly favours evaporation.

A high osmotic concentration can favour condensation - but, it takes a really big osmotic concentration to balance even a moderate relative humidity (e.g. 95%)



10

Equilibrium conditions: evaporation = condensation



Water Potential (kPa)	[Solute] (mOsm)	Equilibrium RH (%)
0	0	100.00
-0.68	277	99.5
-1.36	555	99.0
-6.92	2831	95.0
-14.2	5815	90.0
-30.1	impossible	80.0

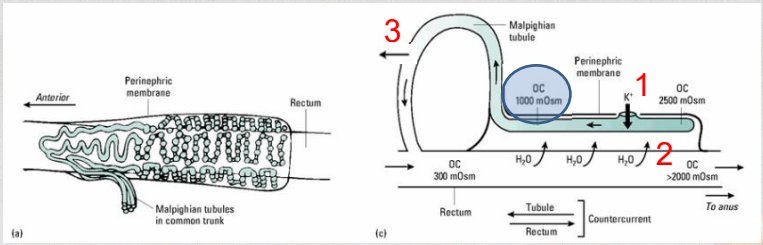
11

Osmotic mechanisms: Insect cryptonephridial system

Meal Worm Larvae

Malpighian Tubules

- Transport KCl into perinephric space (2500 mOsm)
- Resorbs water from rectal lumen (2000 mOsm)
- Fluid recycled to body (1000 mOsm)



Countercurrent multiplier

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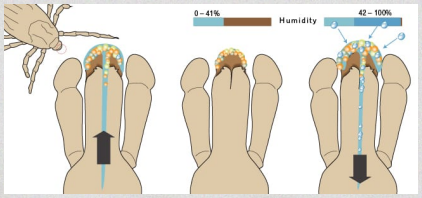
Osmotic mechanisms

Some arthropods use osmotic solutions to absorb water vapour.

Many ticks secrete a KCl-rich saliva which absorbs water vapour from humid air (70-94%) ?!

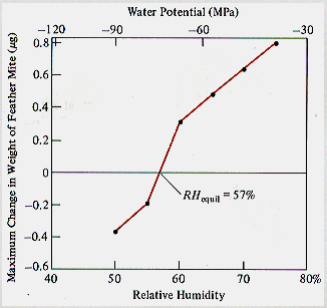


Water Potential (kPa)	[Solute] (mOsm)	Equilibrium RH (%)
-14.2	5815	90.0

13

Non-osmotic mechanisms must operate

This feather mite can absorb water vapour to an equilibrium relative humidity of 57%, which is osmotically impossible!



Water Potential (kPa)	[Solute] (mOsm)	Equilibrium RH (%)
-30.1	impossible	<<80.0

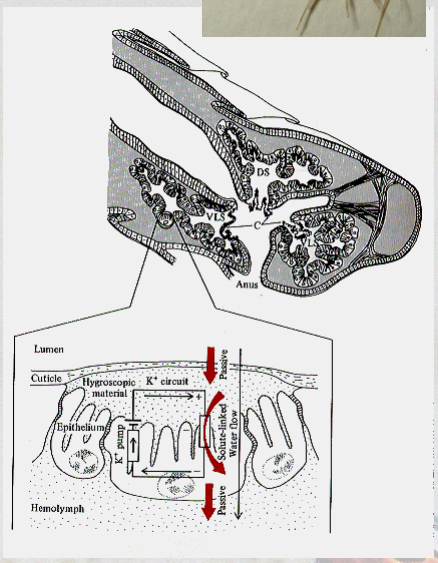
14

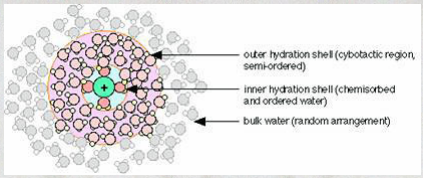
Electro-osmosis

The desert firebrat *Thermobia* (a thysanuran)

Has highly organised rectal papillae which are thought to pump cations (K+?) without bound water, then reabsorb them with bound water.

Process is called electro-osmosis.




outer hydration shell (cybotactic region, semi-ordered)
inner hydration shell (chemisorbed and ordered water)
bulk water (random arrangement)

Works down to 50% humidity

15

Hairy mouth bladders

The desert cockroach Arenivaga

Extrudes labial bladders covered by fine hairs.

These are thought to absorb water vapour by capillarity.

They are then invaginated and somehow the liquid is removed (squeezed off?).

Table 1. Weight changes at 25° and 96% R.H. in animals with part of body surface covered with beeswax/resin mixture

Surface waxed	Rate of weight gain (% initial body weight/day)*	SE	*n*
Control, no wax applied	3.59	0.51	25
Anus	0.87	0.13	18
Dorsal	1.72	0.48	7
Mouth	−1.24	0.15	16
Mouth, wax removed	0.44	0.32	11

16

Insect rectal pads

Hyperosmotic urine

- Ions pumped from stacks to intercellular space and draws water from lumen into intercellular space
- Fluid passes to body space and ions are reabsorbed, leaving fluid dilute

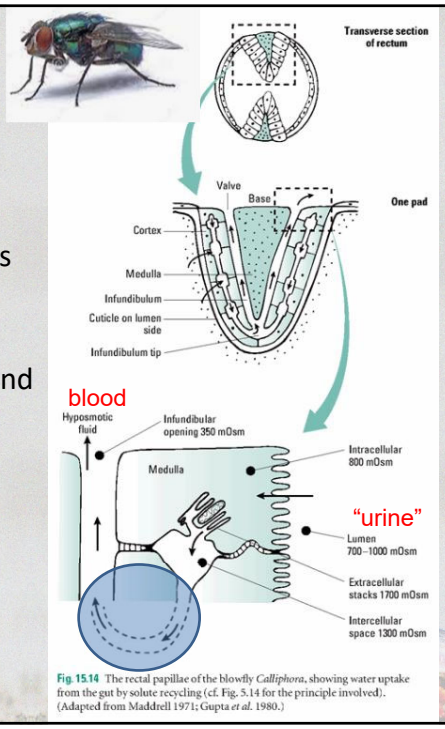


Fig. 15.14 The rectal papillae of the blowfly *Calliphora*, showing water uptake from the gut by solute recycling (cf. Fig. 5.14 for the principle involved). (Adapted from Maddrell 1971; Gupta *et al.* 1980.)

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Urine Concentration

Many brine-animals form highly concentrated urine (esp insects).

Crustaceans use antennal glands (secrete/reabsorb ions) – only limited urine concentrating capacity (U/P ≤ 1).

Insects use rectal glands
– high urine
concentrating capacity
e.g. *Ephydrella* (brine fly)
8700 mOsm!

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Vertebrates

Urine concentrating capacity

Table 15.8 Urine concentrations and urine : plasma ratios in temperate land animals (values are maxima from dehydrate animals).

Group/species	Urine concentration (mOsm)	Urine : plasma ratio
Insects	~1000–5000	~3–15
Reptiles		
Tuatara	270	1.0
Gecko	325	0.7
Iguana	362	1.0
Birds		
Chicken	538	1.5
Pigeon	655	1.7
Pelican	700	2.0
Mammals		
Rat	2900	9
Domestic cat	3100	10
Vampire bat	4650	14
Beaver	520	1.7
Pig	1100	3
Domestic cow	1160	3.7
Human	1400	4–5

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The “lousy” avian kidney

The avian kidney has a poor capacity, and can only moderately concentrate urine.

Why?

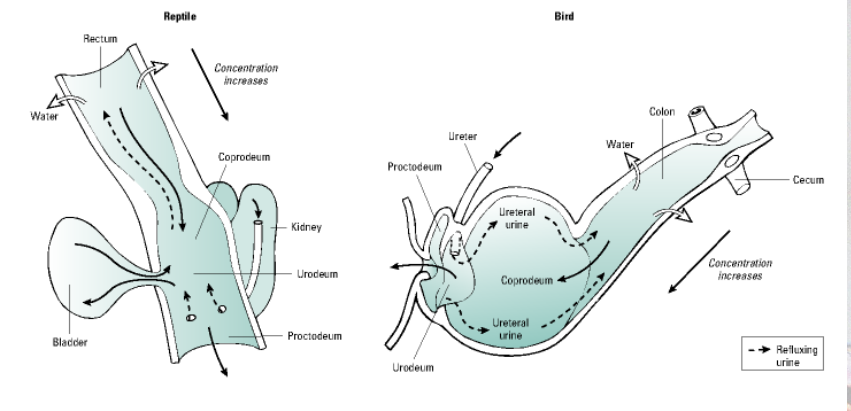
1. Their N waste is uric acid, which is insoluble and can be thick, so it is hard to transport along tubules.
2. Urine is emptied into the hind gut for further processing, which negates the advantage of producing concentrated urine in the first place.

20

Reptiles and birds

Urine mixes with faeces in hind gut

Water resorption occurs here



21

Do birds pee?

The ostrich does – but it is unusual amongst birds

And it's urine is white! (Uric acid)

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